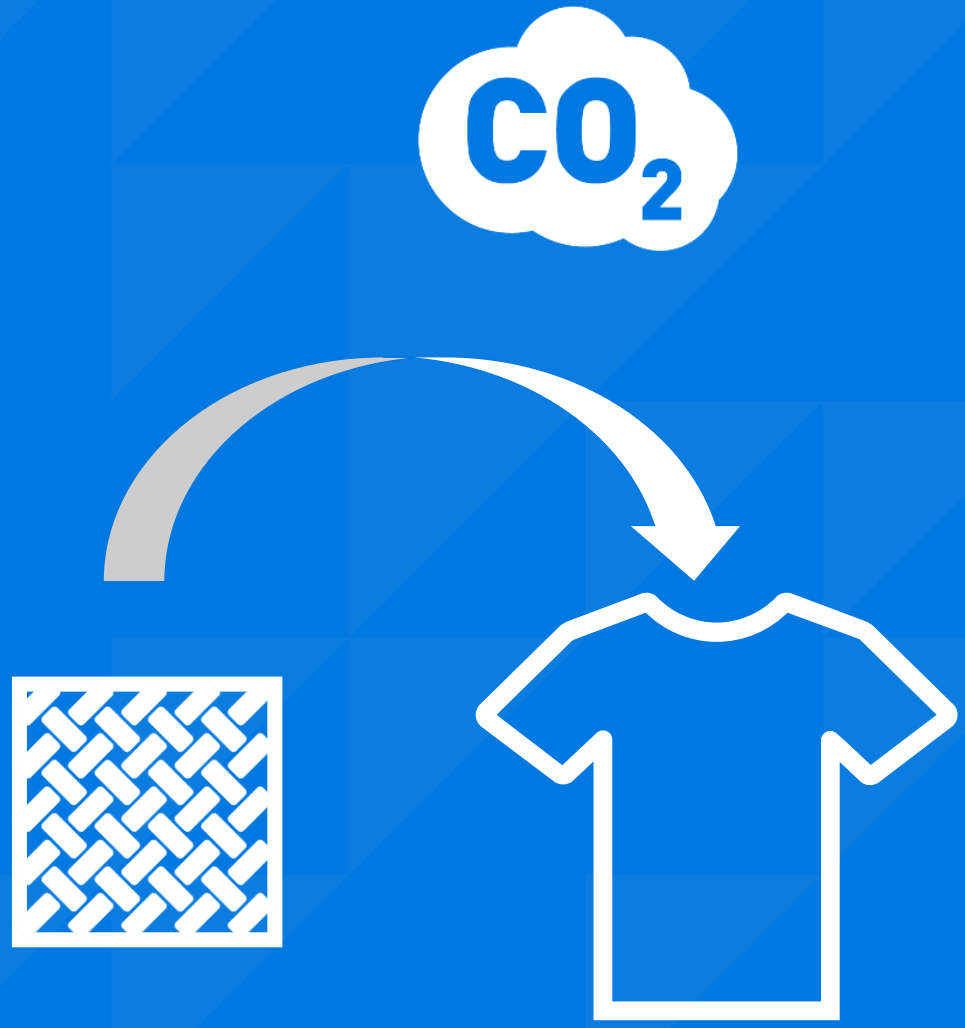
Viegand Maagøe

Textile made from rPET

November 2023

Calculations of climate change impacts from a Nordic Swan Ecolabel sports t-shirt made of rPET in comparison to a market average sports t-shirt



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Viegand Maagøe

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Background

The Nordic Swan Ecolabel

It is possible for textile products to obtain the Nordic Swan Ecolabel if the product lives up to a set of requirements aiming to reduce environmental impacts. Viegand Maagøe has been appointed to calculate the benefit in terms of greenhouse gas emission savings related to choosing a Nordic Swan Ecolabel textile product (generation 5) compared to an average non-Nordic Swan ecolabelled product. In this report, the textile product that has been studied is a sports t-shirt in fossil polyester, however, biobased polyester is also allowed in the Nordic Swan Ecolabel criteria. The scope of the report is thus limited to requirements that directly affect greenhouse gas emissions for the sports t-shirt, and where it is deemed that the effect of the requirements is quantifiable. It should, however, be highlighted that to obtain the Nordic Swan Ecolabel in this category, a product needs to meet other requirements that are also beneficial both to the environment and the climate, but which are not accounted for in this project. The project thus focus only on the requirements related to rPET (recycled polyester) and elastane content.

Greenhouse gas emissions: more than CO_2

For simplicity, throughout this report the abbreviation GHG means greenhouse gasses. GHG consist of many different gasses, the most abundant being CO_2 (carbon dioxide), CH_4 (methane), N_2O (nitrous oxide), and water vapor, besides some synthetic gasses like fluorinated gasses*. We consider all greenhouse gasses and express them in $kgCO_2$-equivalents ($kgCO_2$-eq). This conversion is based on characterization factors from IPCC 2021 GWP100a.

Case relevance

Many textile products are made fully or partially from polyester. The fraction of recycled polyester varies substantially from product to product, but looking at the global market, recycled material is estimated to make up 14% of all polyester produced. To assess the impact of the ecolabel requirement on recycled content and elastane, it is important to obtain knowledge on the material impact and the market.

Nordic Ecolabelling

Nordic Ecolabelling is the commissioner of the study. Nordic Ecolabelling is interested in knowing how ecolabels can support the green transition. They are specifically interested in calculations and associated methodological considerations of the GHG emission savings connected with choosing an ecolabelled product or service compared to choosing a reference alternative. The intended application of the study is marketing and communication.

Abbreviations

For simplicity, the following abbreviations are used throughout the report:

- Nordic Swan ecolabelled is abbreviated to ecolabelled
- Non-Nordic Swan ecolabelled is abbreviated to non-ecolabelled

* Further reading: https://www.epa.gov/ghgemissions/overview-greenhouse-gases

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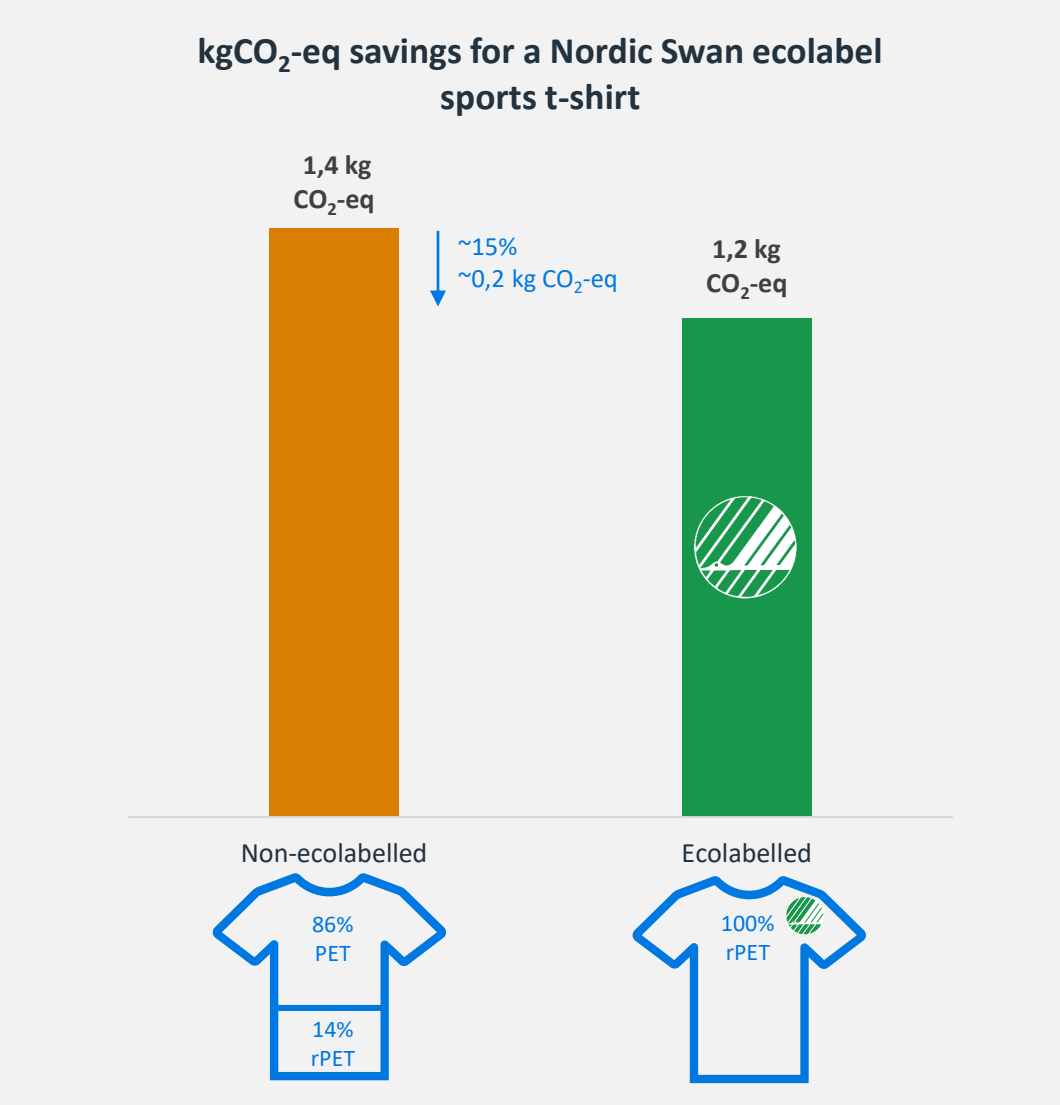
1. Executive Summary

A Nordic Swan Ecolabel sports t-shirt: Executive summary

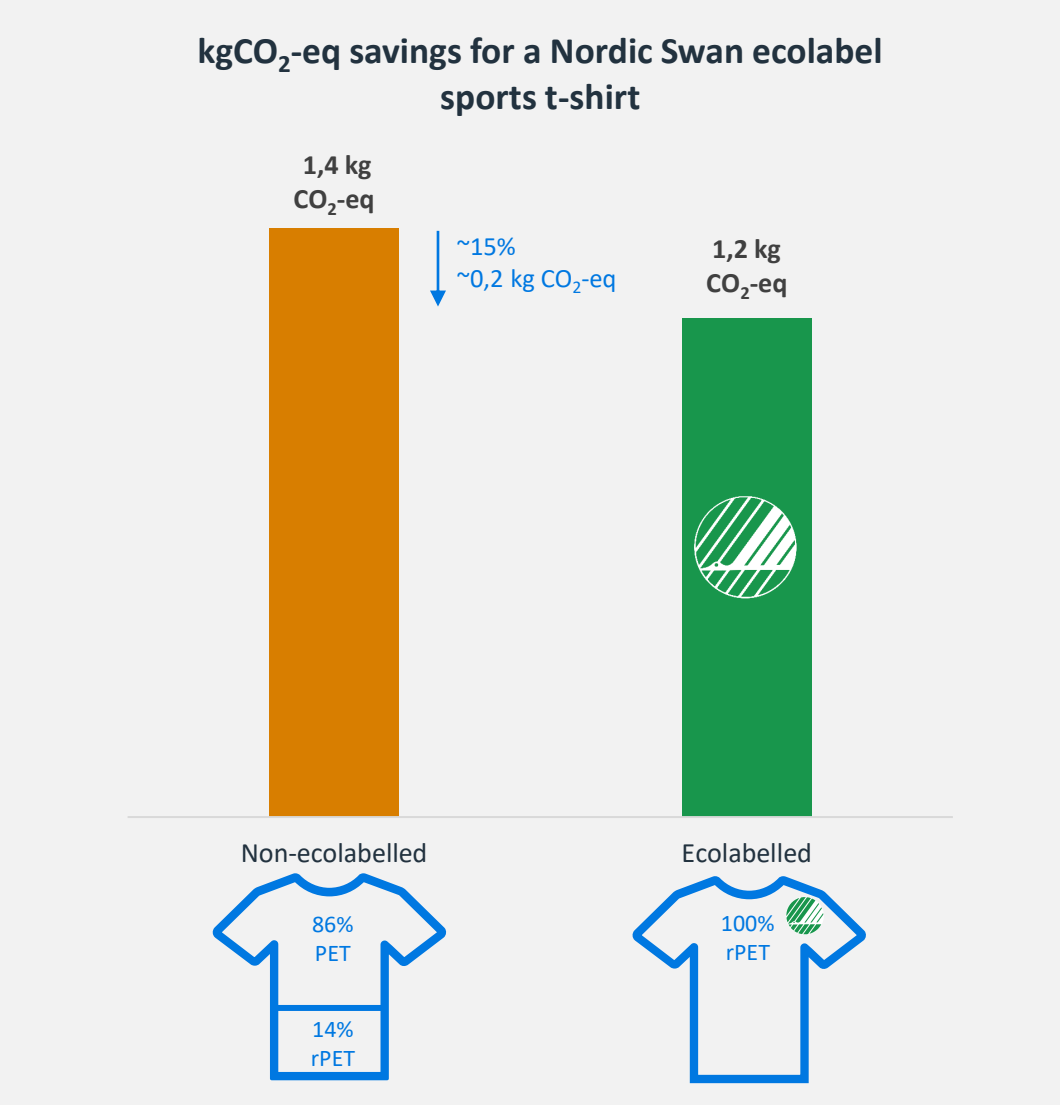


By choosing a Nordic Swan Ecolabel sport t-shirt you can potentially save 15% of CO_2-eq emissions related to the raw material extraction and production of the sports t-shirt. This amounts to a saving of approx. 0,2 kg of CO_2-eq. In this case, the Nordic Swan Ecolabel shirt is assumed to be of 100% rPET and the non-ecolabelled, market-average sports t-shirt to contain 14% rPET and 86% newly produced PET.

This study focuses only on CO_2-eq emissions and does not quantify any other impact categories. The 0,2 kg CO2-eq reduction is only on cradle-to-gate emissions and does therefore the savings on a full life cycle perspective are not quantified.

The Nordic Swan Ecolabel has many more criteria for the analysed textile product than included in this calculation. The excluded criteria on quality might lower the life cycle CO_2-eq emissions per use, as they allow for the sports t-shirt to potentially be used more times. However, the number of uses is completely up to consumer behaviour, and it is uncertain whether a better quality leads the consumer to use the sports t-shirt more times than a non-ecolabelled alternative.

A Nordic Swan Ecolabel sports t-shirt of recycled PET emits ~15% less GHG-emissions than a comparable average non-ecolabelled market alternative



Description

For synthetic textiles, the Nordic Swan Ecolabel requires the use of 100% recycled material or bio-based material. In this study, the focus is on a sports t-shirt of 100% recycled material.

A Nordic Swan Ecolabel sports t-shirt of polyester **must contain 100% rPET** but can include up to 10% elastane (see sensitivity analysis on page 9 for elastane's impact). In the example to the left, no elastane is included. The market average t-shirt **contains 14% rPET and 86% newly produced PET**[1]. This assessment focuses exclusively on greenhouse gas emissions from the production of a sports t-shirt and does not look at other environmental parameters. The focus of this study is only the life cycle phases before sale and use of the product, namely the raw material acquisition and production. Therefore, this study has a **cradle-to-gate** focus.

The cases

The study aims to quantify **potential savings** in greenhouse gas emissions due to requirements for the recycled content of synthetic textiles at the Nordic Swan Ecolabel. In the figure below the graph to the left, the two different cases can be seen.

The 14% of rPET in the market average, not Nordic Swan ecolabelled, alternative is based on the amount of rPET in the global PET textile production and not based on a comparison of a specific t-shirt type or brand.

Excluded requirements

The **Nordic Swan Ecolabel** is a holistic ecolabel that considers multiple aspects (entire life cycle and other environmental parameters) than those calculated here. In addition to the selected requirement, several requirements may be relevant in relation to the total greenhouse gas emissions e.g. requirements on quality, energy efficient production processes and chemicals. However, these are not included in the calculation. Some requirements are excluded, as they are difficult to quantify or obtain data on, but they may still have an impact on the overall climate and environmental impact. The Nordic Swan Ecolabel also has criteria for textile of other fibre types than the synthetic textile in this study.

1: Textile exchange (2022): Material Change Insights 2022

Nordic Swan Ecolabel is a holistic ecolabel and has many criteria that have not been quantified in this study

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Excluded requirements

The **Nordic Swan Ecolabel** is a holistic ecolabel that considers multiple aspects (entire life cycle and other environmental parameters) than those calculated here. In addition to the selected requirement, several requirements may be relevant in relation to the total greenhouse gas emissions such as requirements on quality, energy efficient production processes and chemicals. However, these are not included in the calculation. Some requirements are excluded, as they are difficult to quantify or obtain data on, but they may still have an impact on the overall climate and environmental impact.

Example of requirements on quality

072 - Tear strength

Woven fabrics must comply with the levels specified table below for tear strength according to the ISO 13937-1 standard. The requirement must be documented for a representative samples of the whole Nordic Swan Ecolabelled collection.

O71 Dimensional changes during washing and drying

There are specified limits for how much dimensions of the textile may change based on the textile application.

Example of criteria on energy efficient production

O48 - Implementation of BAT for energy and water consumption

The applicant has to demonstrate that the energy used is measured and compared with BAT levels or compared with own figures from before implementing efficiency techniques.

Example of criteria on chemicals

O34 - Prohibition of CMR substances

Chemical products shall not contain any ingoing substances that are part of the hazard classes carcinogenicity, Germ cell mutagenicity, reproductive toxicity.

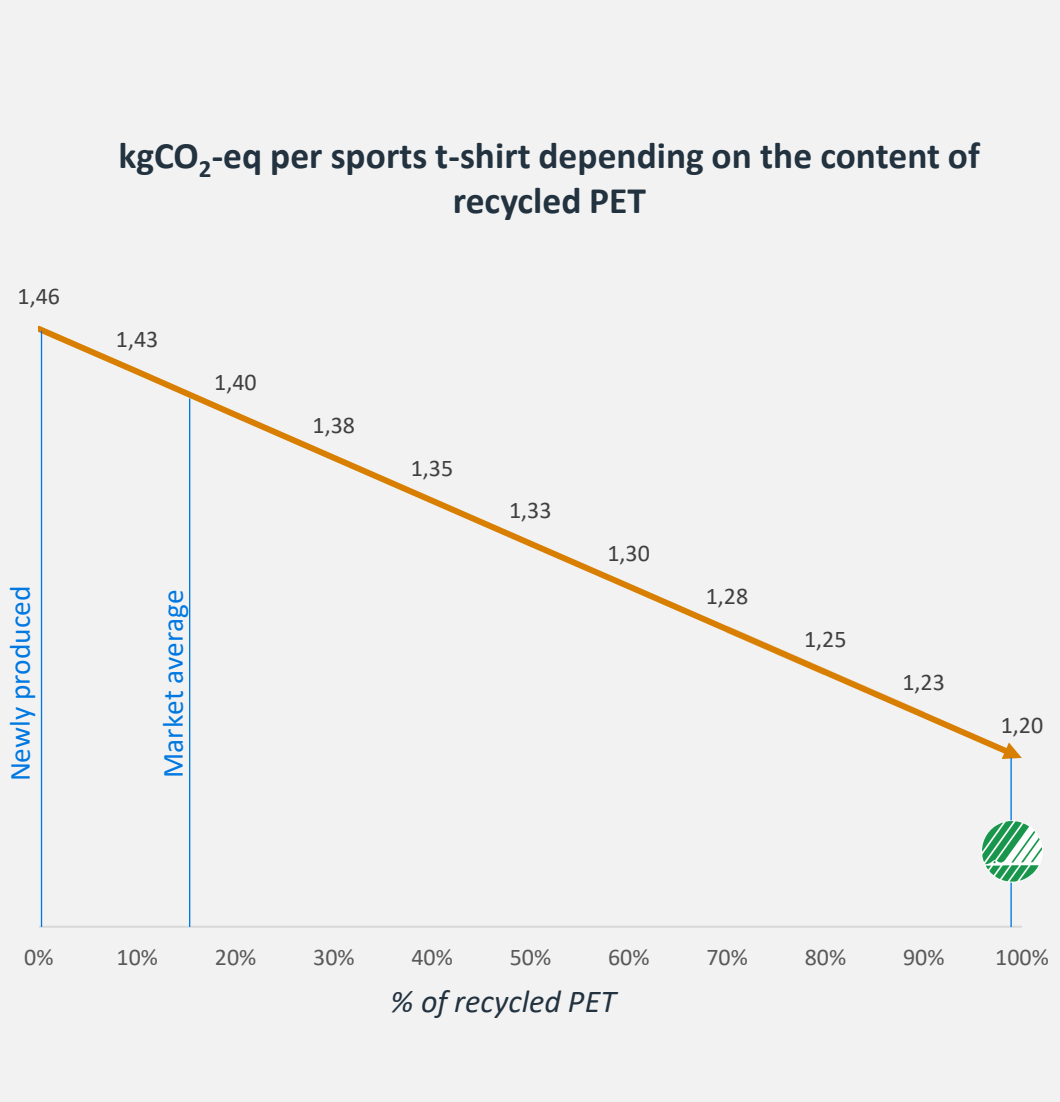
O35 - Prohibited substances

The Nordic Swan Ecolabel has multiple criteria for substances that cannot be used. See the criteria O35 for specification.

O30 - Recycled fibres, test for environmentally harmful substances

Specific substances may not be above certain limits. Must be proven by Oeko-Tex standard 100 class I certificate or a test report.

CO_2-eq savings from choosing a Nordic Swan Ecolabel sports t-shirt depends on the rPET content of the alternative



Description

There is a **linear correlation** between the amount of rPET in a t-shirt and the GHG emissions as a result of the included processes in this study. This correlation is presented on the left. The comparison is solely of the **cradle-to-gate** emissions, meaning the raw material extraction and production.

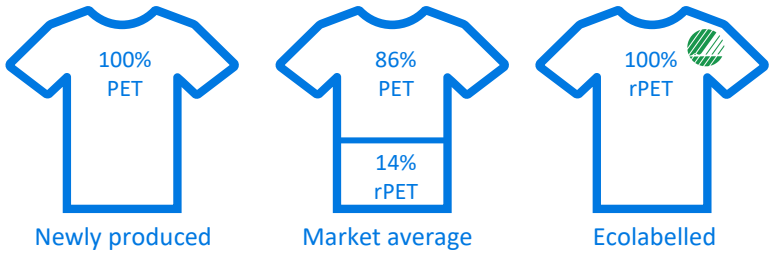
There is a **total saving of 0,26 kgCO_2-eq or ~18% per sports t-shirt** when comparing a Nordic Swan Ecolabel sports t-shirt to a t-shirt of 100% newly produced PET. In a comparison with the market average, non-ecolabelled sport t-shirt that consists of 14% rPET and 86% newly produced PET, there is a potential saving of **0,21 kgCO_2-eq or ~15%** if a Nordic Swan Ecolabel sports t-shirt is chosen instead.

The market average

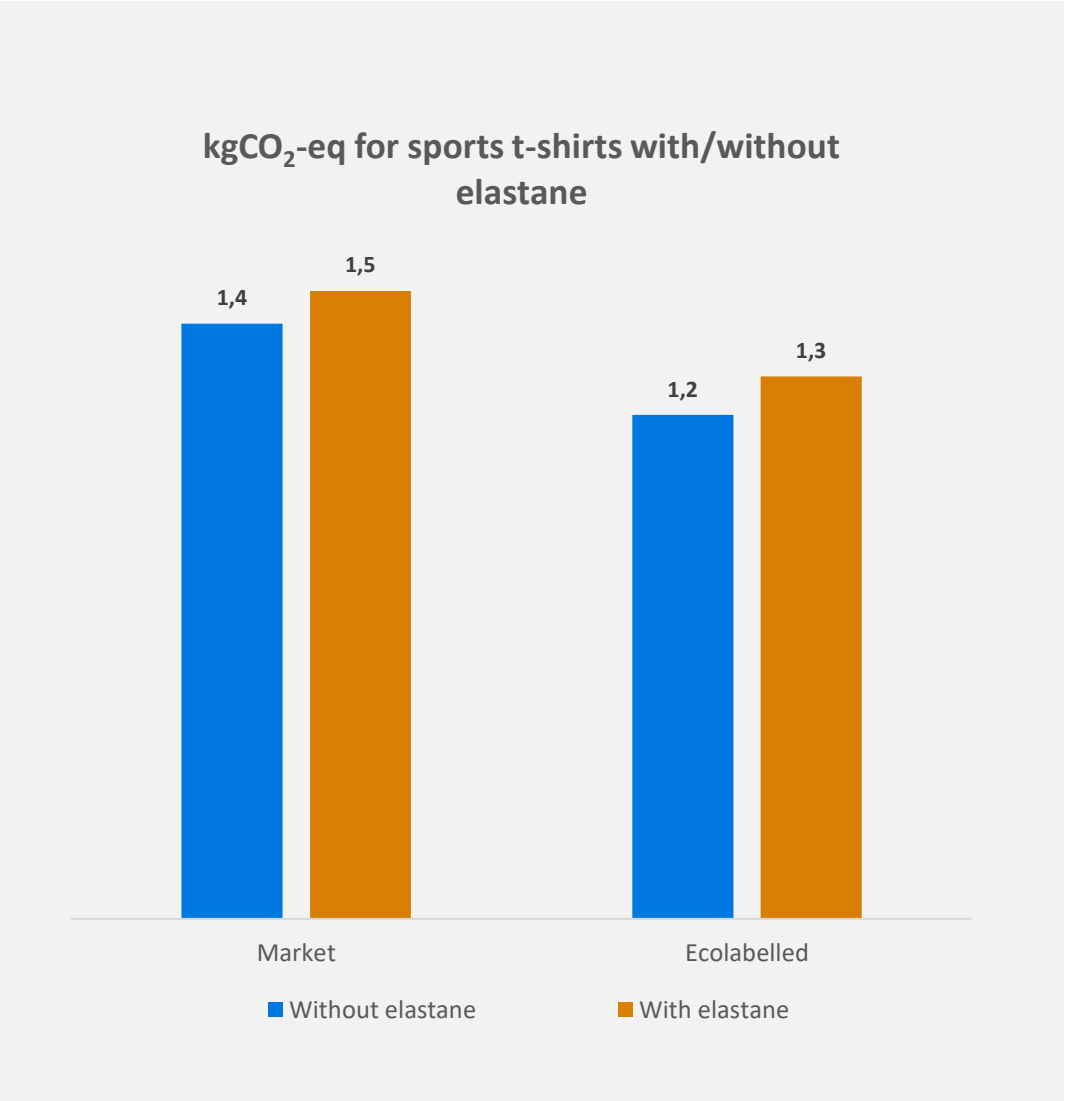
The global market average might be different from the current market average in the Nordic Countries where the Nordic Swan Ecolabel is primarily located. Therefore, the average saving in the Nordic countries might be different from the average global saving.

The definitions of the shown sports t-shirts

Below is shown the material composition of the sports t-shirts marked in the graph on the left:



Elastane content has a very small influence on the total CO2-eq emissions of the ecolabelled sports t-shirt, but should be avoided if possible

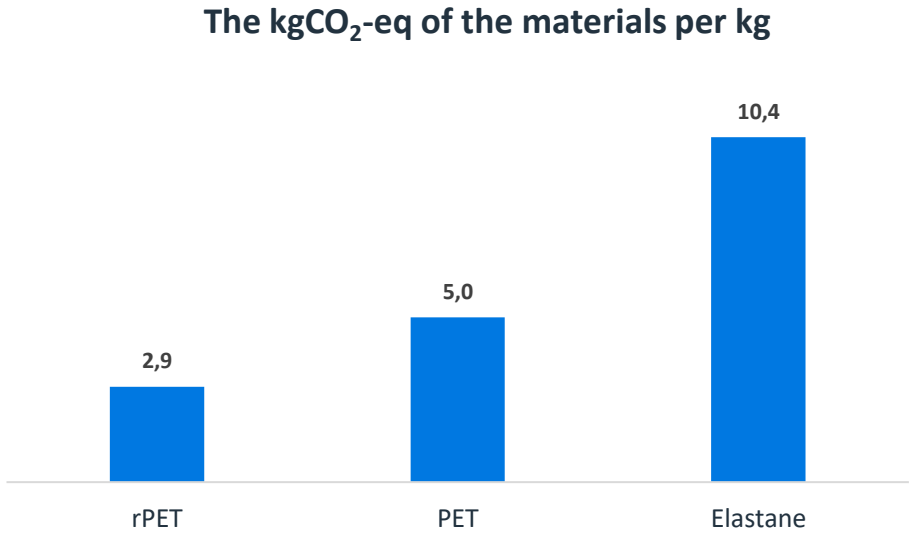


The requirement

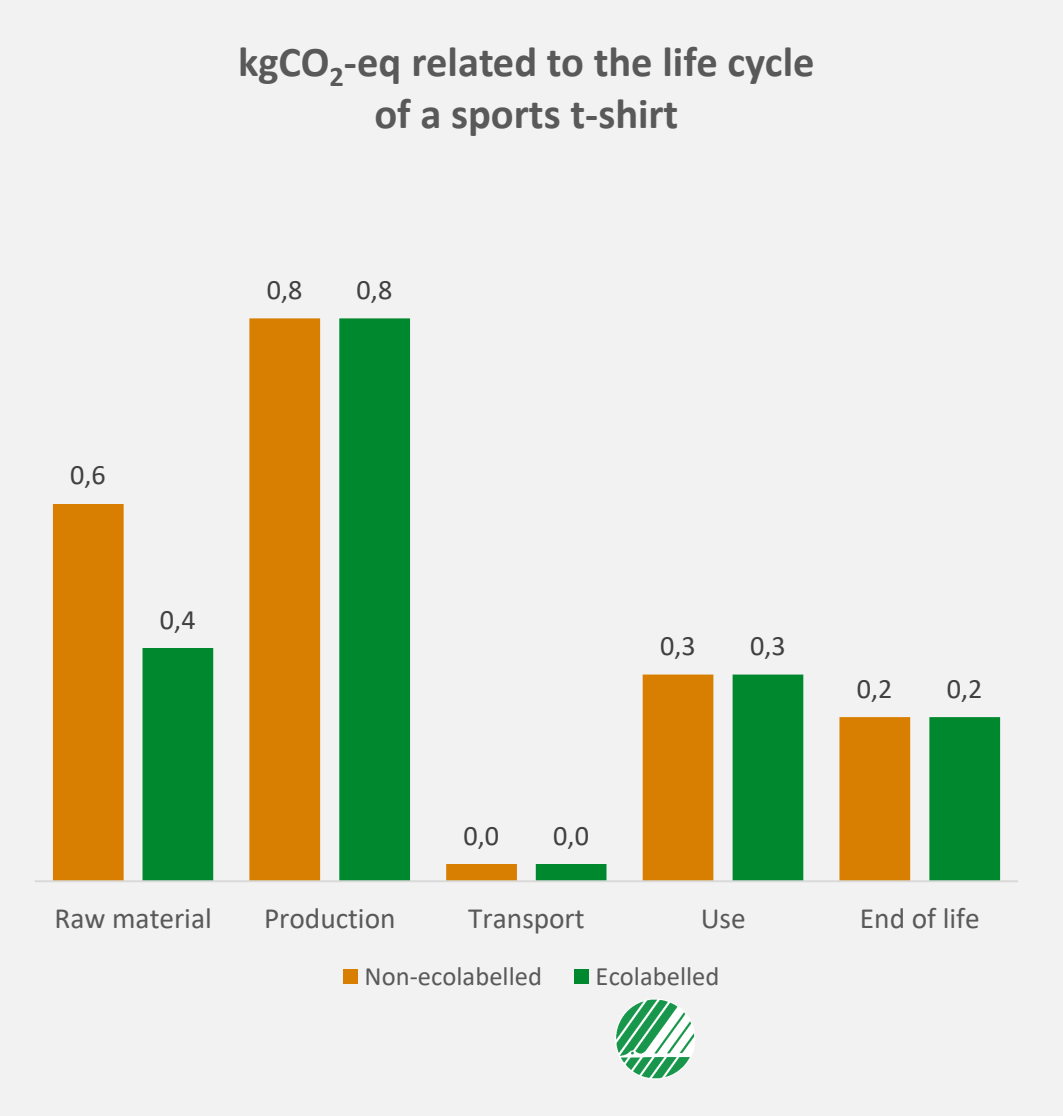
According to the Nordic Swan Label, up to 10% of new elastane is allowed in the synthetic textile, which otherwise must consist of 100% rPET. The inclusion of 10% elastane does not change the result significantly as it becomes a very small amount when it is only 10% of the weight of the t-shirt, as can be seen on the graph to the left.

Climate change impact of elastane

As seen in the graph below, elastane is responsible for twice as many CO_2-eq emissions pr. kg than the PET materials that are the most prevalent in the sports t-shirt. This means that it is generally a good idea to go with a sports t-shirt that has a lower amount of elastane, as this will mean the sports t-shirt has a slightly smaller CO_2-eq emission.



~68% of the life cycle GHG-emissions of the sport t-shirt comes from the raw material and production – the two life cycle phases that have been included in this study.



Description

For a sensitivity analysis, a calculation of the CO_2-eq emissions throughout the lifecycle has been done as shown on the figure on the left. Looking at the entire life cycle of a sports t-shirt it becomes apparent that the biggest contributor to the climate change impact is the production phase. The CO_2-eq emissions from the production phase is 0,8 kg CO_2-eq per sports t-shirt. The end-of-life scenario included in the sensitivity analysis is waste incineration with energy recovery. For the use phase included in this sensitivity analysis, 44 times of washing is included, based on the number of uses specified in the PEFCR for textile and apparel[1]. It should be noted, that if the calculation was based on "one wear" the emissions from the use phase would be lower. The Nordic Swan Ecolabel sets several quality requirements for the t-shirt that could potentially extend its lifecycle; however, these are not possible to quantify in this study.

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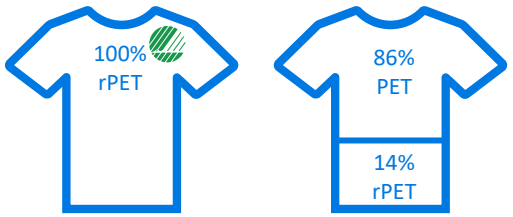
This study focuses exclusively on GHG emissions from the raw materials and production of a sports t-shirt (cradle-to-gate emissions). The assessment focuses only on the cradle-to-gate emissions as these are the parts of the life cycle that the Nordic Swan Ecolabel has quantifiable criteria for. Furthermore, the study does not look at other environmental parameters than CO_2-eq emissions.

The compared sports t-shirts

The sports t-shirts compared in this example consist of the following material mix:



The 14% of rPET in the non-ecolabelled alternative is based on the amount of rPET in the global PET textile production and not based on a comparison of a specific t-shirt type or brand.

1: Quantis (2022), Draft product environmental footprint category rules (PEFCR), Apparel and footwear.

Methodology – The LCA is calculated based on an attributional, cut-off system model

A life cycle assessment (LCA) of a sports t-shirt made of rPET has been performed, focusing exclusively on GHG emissions

The methodological framework for the performed LCA of a sports t-shirt made of PET is:

Attributional: Attributional LCA is chosen as it compares two existing alternatives (ecolabelled and market average non-ecolabelled), and thus uses average market data, rather than marginal data used in consequential LCA. Attributional LCA is also used to avoid uncertain assumptions about avoided or increased production in secondary systems. In attributional LCA, assumptions are made about the proportion of a process that is allocated between systems when multi-functional processes occur. The system model '**allocation - cut-off by classification**´ is used, which determines the way waste and recycling scenarios are modelled. This is also the method used in the Product Environmental Footprint methodology of the European Union.

The results are both presented primarily as Cradle-to-gate.
However, for a full life cycle perspective, Cradle-to-grave is shown as well.

Cradle-to-gate: This approach excludes the use and disposal phase. This is because these will be the same for both ecolabelled and non-ecolabelled sports t-shirts, and they are out of the control of the textile producer. This makes it possible to see the effect on the part of the life cycle which the requirements affects.

Cradle-to-grave: This approach looks at the impacts from the whole life cycle including all life cycle parts from the cradle-to-gate approach but adds the use phase and the disposal at end-of-life. Including this in the results is necessary to show the effect of the requirements on the full life cycle impact of the sports t-shirt, for proportionality.

Functional unit: The functional unit is defined as ”1 sports t-shirt in a unisex size M, made of polyester, sold on the Nordic market”. The functional unit makes it possible to compare the effect of choosing a sports t-shirt from an ecolabelled textile producer as opposed as the market average non-ecolabelled textile producer.

IPCC 2021, GWP100a: is the used LCIA-method (Life Cycle Inventory Assessment), which was developed by IPCC (Intergovernmental Panel on Climate Change) and last updated in 2021. The assessment method calculates climate impact in CO_2-equivalents (CO_2-eq) over a time period of 100 years. Thus, the other impact categories included in a conventional LCA are not included in this analysis.

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2. Overview of LCA methodology

Life Cycle Assessment methodology

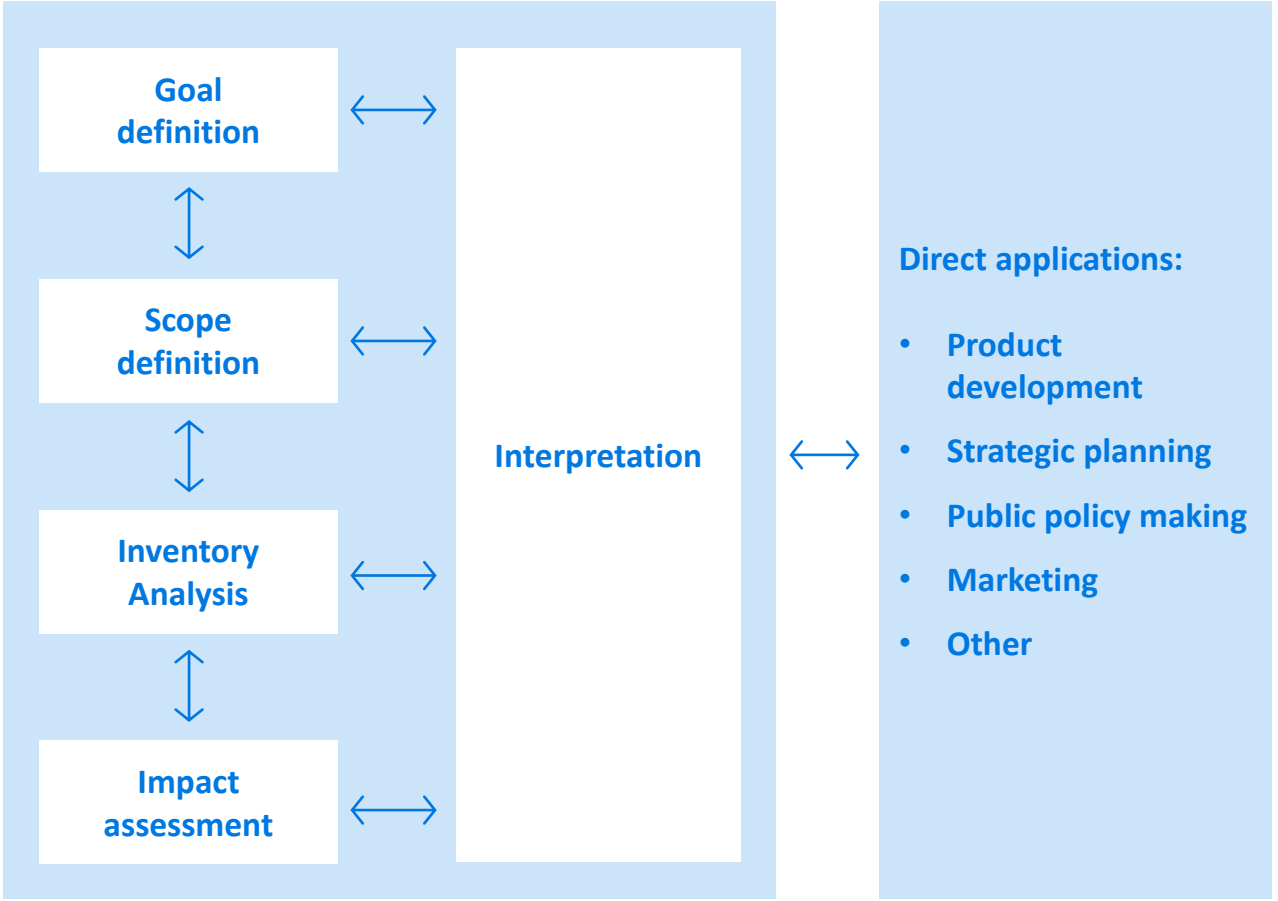
The climate change impact calculations in this study are based on LCA methodology.

LCA consists of five main steps:

- Goal definition: The purpose of the LCA, including audience
- Scope definition: Functional unit, reference flows, methodological choices, system boundaries and system description.
- Inventory analysis: Data collection and modelling of elementary flows, which are inputs and outputs to and from the system. Scaling of flows to match the functional unit.
- Impact assessment: Calculations to translate elementary flows from the inventory analysis into environmental impacts in different categories (such as climate change).
- Interpretation: conclusions and recommendations based on the above. Can include comparisons, hotspot analysis, sensitivity analysis, normalisation.

LCA is an iterative methodology, which is why the arrows in the figure point in both directions.

Note that this study focuses solely on greenhouse gas emissions to create a carbon footprint. It does not include analysis of other environmental impact categories.



Source: Hauschild et al. 2018. Figure adapted from figure 6.1 in Hauschild et al. 2018

The LCA uses the system modelling – Attributional, Cut-off

Life Cycle Assessment (LCA) is a methodology to calculate the possible environmental impacts related to a certain product or system. Depending on the system complexity and the purpose of the LCA, different modelling approaches and ways of allocating impacts across systems can be used. There are two overall modelling approaches:

- **Attributional** tries to answer the question ”Which environmental impacts have the manufacture, use, and disposal of the product or service led to/ will lead to?”
- **Consequential** tries to answer ”Which environmental impacts will occur as a consequence of choosing to manufacture, use, and dispose of the product or service and what impacts will changes in manufacturing method, use, and disposal of the product or service lead to?”

In this assessment the system modelling approach ”**Attributional**” and the allocation method ”**Cut-off**” is used.

In LCA systems, there are often processes with multiple outputs, i.e. a product, a by-product, waste for treatment, and waste for recycling. This means that impacts from the multifunctional processes must be divided (allocated) between the products, by-products, and wastes. In the modelling of this system, there are no multifunctional processes, neither for the ecolabelled nor the reference scenario.

The recycled material is modelled according to “the polluter pays”-principle

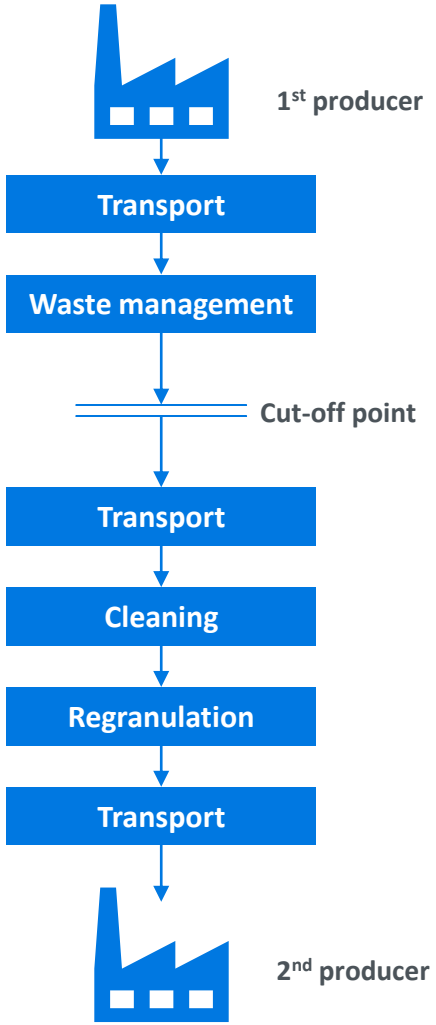
Fundamental to this study is the consideration for recycled material. However, the impact of recycled material can be discussed.

Using the cut-off approach, a “polluter pays”-principle is applied. Herein, the producer that utilized virgin material pays for the CO2-eq emissions related to the raw material extraction and material production. Thereby, the recycled materials are available burden-free.

This creates an incentive for producers to make use of recycled material, as they can thereby lower their CO2-eq emissions. However, it does not provide a direct benefit to the producer who sends waste material to recycling.

This perspective on recycled material makes sense in the current market, where there is still more demand for the virgin material compared to the recycled material, for which reason an incentive is needed. In a market where the demand for recycled plastic is higher than that for virgin plastic, this choice of allocating the impact between different life cycles would not make sense.

The cut-off between the different life cycles (1st producer and 2nd producer) is placed as shown in the figure on the left. The 2nd producer gets the material for free but must still pay for the processes associated with the regranulation and transport of the plastic waste.



Read more about the attributional cut-off system model here: https://ecoinvent.org/the-ecoinvent-database/system-models/

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3. Goal and scope

Purpose

The purpose of the assessment

The purpose of the project is to conduct a comparative LCA to calculate the potential savings in Green House Gas (GHG) emissions associated with choosing an ecolabelled sports t-shirt compared to an average non-ecolabelled alternative.

Nordic Swan wish to push the market, in order to speed up the green transition. In that regard, the Nordic Swan is interested in increasing their knowledge regarding the climate impact of the label, to evaluate the criteria.

The project focuses on GHG-emissions relating to the use of recycled polyester compared to virgin polyester in a sports t-shirt – while also considering the label exception permitting up to 10% of virgin elastane. The upstream activities such as resource extraction, pretreatment and production of fibres, and sewing the finished garment are included in the LCA. Furthermore, downstream activities such as distribution, use and disposal of the garment is included in a separate calculation, to be able to show the effects of the criteria in a full life cycle perspective.

Target Audience

The target audience for the study is both Nordic Ecolabelling, who has commissioned the study, and their target audiences for communication and marketing. Thus, the results of the projects are for internal as well as external use. The target audience is mainly within the Nordic region but could also be in the rest of Europe.

This study focuses solely on climate change impacts, also called carbon footprint, for simplicity in communication of the results.

Examples of target groups for the communication and marketing of Nordic Ecolabelling could be:

- Citizens
- Public procurers
- Ecolabelled textile producers
- Non-ecolabelled textile producers (but could be interested in getting the label)
- Other product or service-corporations (marketing)

Functional unit

1 sports t-shirt in a unisex size M, made of polyester, sold on the Nordic market

The functional unit must be easy to communicate and relate to for the target group, and therefore the functional unit consists of the production of 1 sports t-shirt of polyester material delivered to the Nordic market and sold there. Furthermore, in some calculations a use-phase and end-of-life phase located in the Nordic is assumed. The amount of fabric needed for the shirt is based on a unisex size M shirt, following the standard set in the draft PEFCR for textiles and apparel[1].

Ecolabelled reference flow

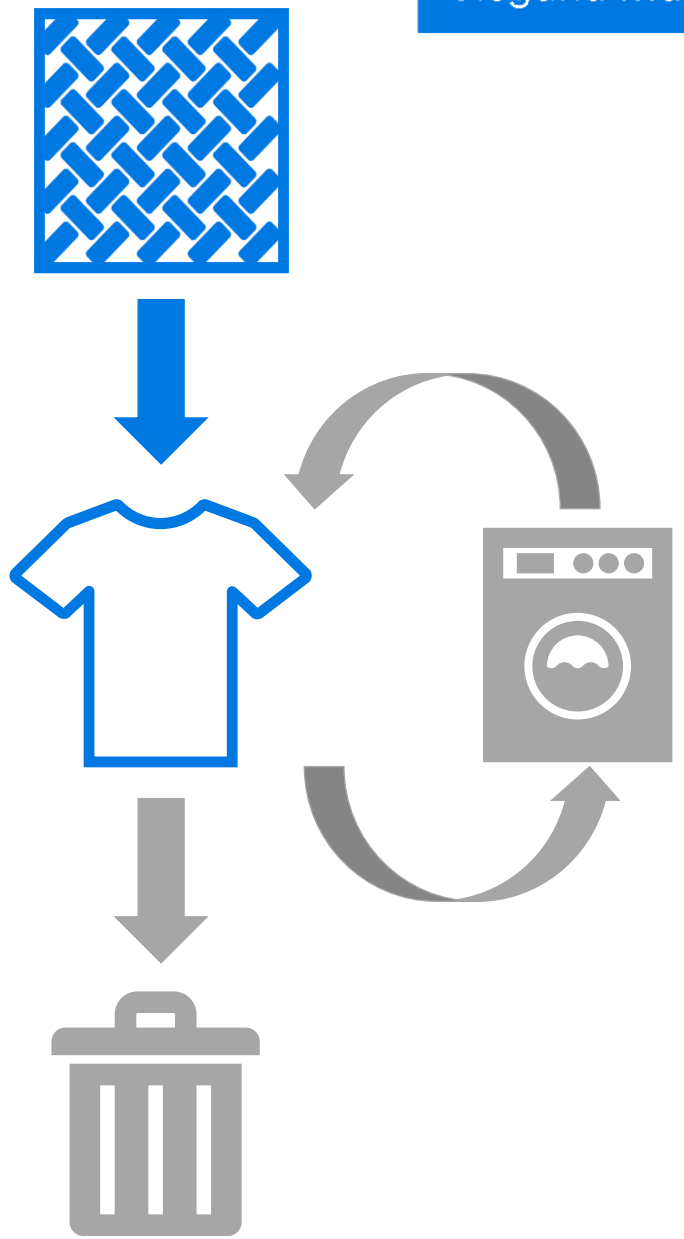
1 ecolabelled sports t-shirt of 0,122 kg* polyester textile produced globally**.

Non-ecolabelled reference flow

1 non-ecolabelled sports t-shirt of 0,122* kg polyester textile produced globally**.

**The weight of the sports t-shirt was determined by a small market research with the aim to identify an average weight.*

***for the sensitivity analysis with the full life cycle the t-shirt is transported to the Nordic market and sold, used 45 times and assumed to be washed 44 times and disposed of in the Nordic countries.*



1: Quantis (2022), Draft product environmental footprint category rules (PEFCR), Apparel and footwear.

System boundaries

Goal and Scope

The following system boundaries are applied:

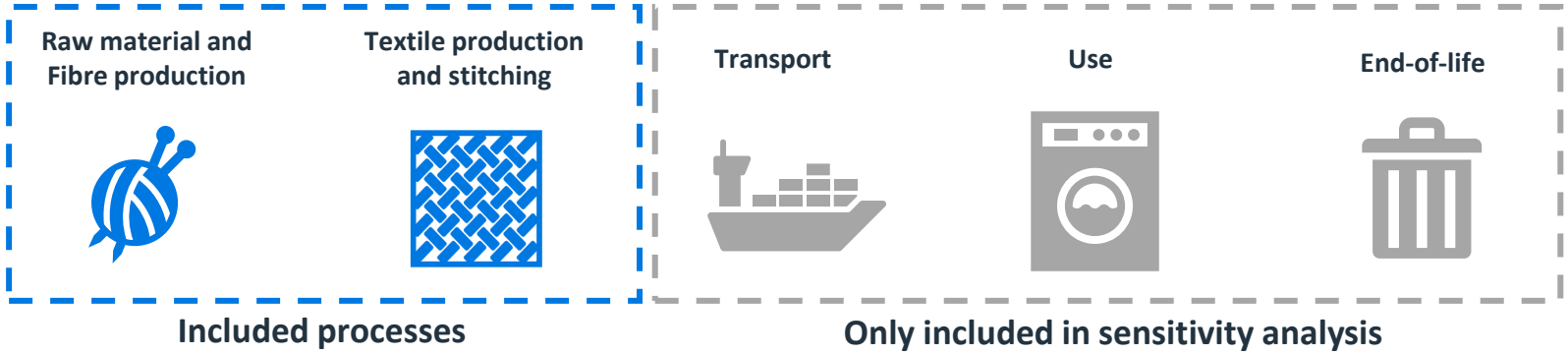
- The assessment focuses solely on the difference in raw material input
- The remaining processes are assumed the same, independent of the raw material input.
- The use phase used in the sensitivity analysis includes emissions related to washing the clothes in the Nordic countries. The electricity and heat mix is a Nordic mix based on the number of inhabitants in the 5 Nordic countries: Denmark, Sweden, Norway, Finland and Iceland.
- The geographical scope for the process from cradle-to-gate (raw material extraction and production) is global
- The geographical scope for the use phase and end-of-life is the Nordic countries: Denmark, Sweden, Norway, Iceland and Finland

The following processes are included and assumed to be the same for the two systems:

- Spinning of yarn, fabric manufacturing, wet processing, dyeing, final cutting, distribution and use.

The following processes are excluded:

- Transport from the store and to the consumer
- Transport to waste processing
- Packaging material for distribution of the finished shirt



Nordic Swan criteria

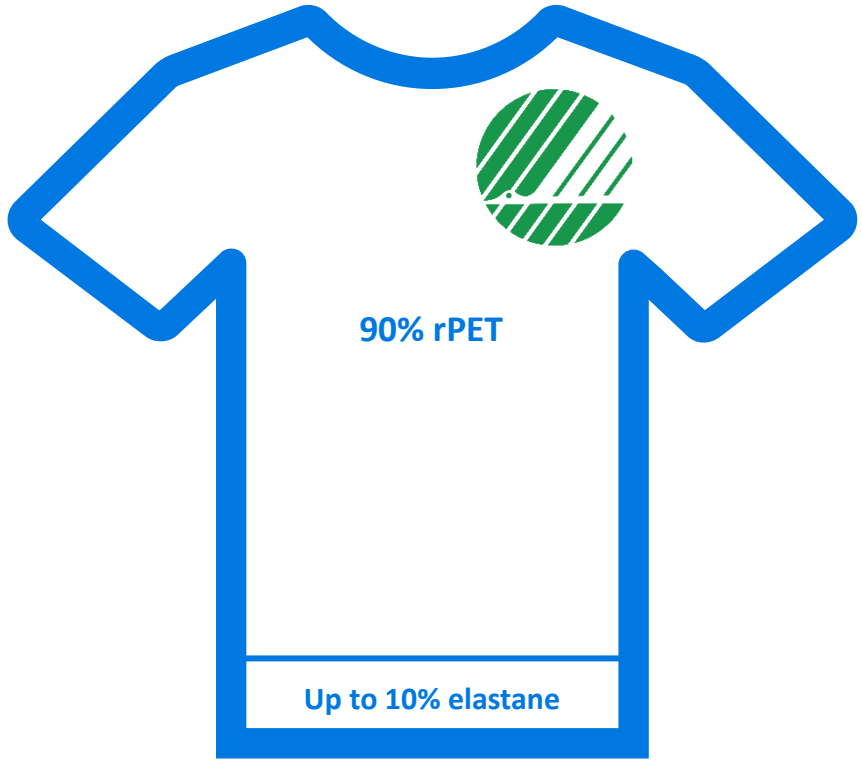
The Nordic Swan ecolabel criteria included in the assessment and its exception

The case of the ecolabelled sport t-shirt is based on the criteria for synthetic textiles included in the Nordic Swan Ecolabel criteria for product of textile, hides/skins and leather. The criteria includes more reduction criteria than the ones presented below, however, those are not possible to quantify a direct CO_2-eq saving on.

O28 Synthetic fibre – fossil origin
"Synthetic fibre of fossil origin must comprise 100% recycled material. This must not include recycled plastic from plants that are EFSA** or FDA*** approved as food contact material or marketed as compatible with these"*

Exception
"For elastane fibres that are STANDARD 100 by OEKO-TEX (annex 4 class II) certified, an exception is given for up to 10% elastane fibres in the fabric"

One requirement that has not been quantified in terms of GHG-emissions in this report is the requirement on the allowed grade/quality of rPET. The requirement states that the rPET must not come from a food-grade approved recycling plant. This requirement is of great importance when looking from a circularity perspective. Plastics that are to be in contact with food has the strictest requirements in terms of contaminants. PET that is used for foods, can be recycled and used for food applications again, but if the food-grade PET is used for a non-food application, it can never go back to be used for food-grade applications again. Thus, using food-grade PET for non-food applications essentially downgrades the plastic, as it greatly limits its area of application after recycling.



* Recycled material is defined here in line with ISO 14021 using the following two categories as specified and covers both mechanical and chemical recycling.
** In line with Commission Regulation (EC) No 282/2008 of 27 March 2008 on recycled plastic materials and articles intended to come into contact with foods.
*** In line with the Code of Federal Regulations Title 21: Food and Drugs, PART 177 – INDIRECT FOOD ADDITIVES: POLYMERS

The market average shirt

The rPET content in the market average shirt is based on global market average

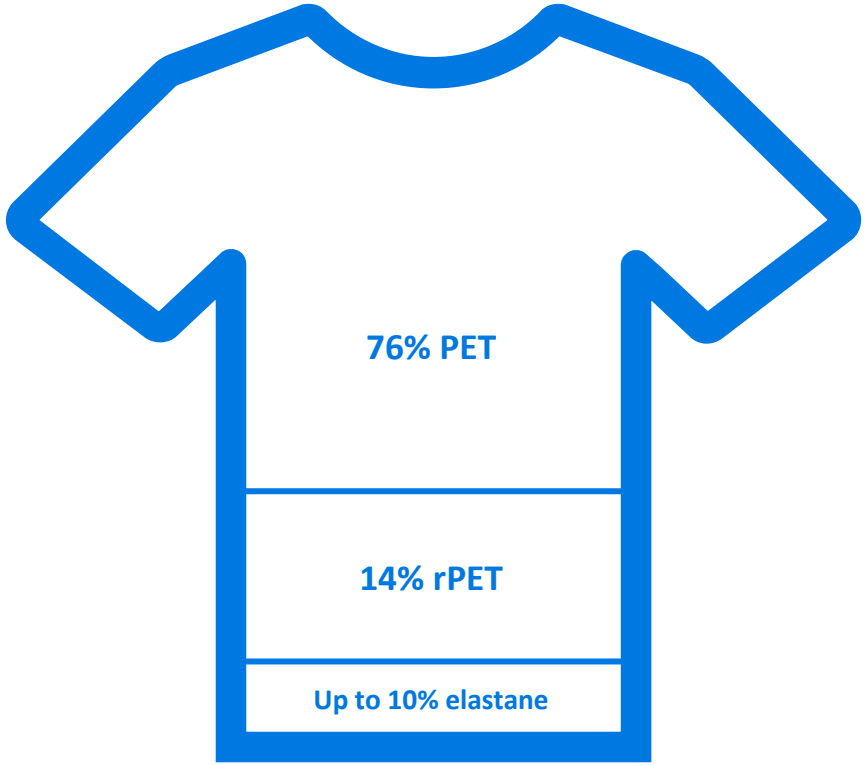
The market average t-shirt that is used for comparison with the eco-labelled t-shirt in this study, is based on the proportion of recycled PET (rPET) in the global PET production[1]. However, within the Nordic market, you can find sports t-shirts with rPET content that may exceed or fall short of the global market average.

The global market average is chosen as it was not possible to obtain specific market data for the Nordic countries nor Europe, despite efforts including reaching out to industry organizations. A reason for this is, that the textile market is very much globalised.

To enhance the reliability of the market average t-shirt composition, a more extensive assessment of products in the Nordic market would be necessary to collect primary data from manufacturers. However, such an endeavour was considered too resource-intensive to be carried out within the scope of this study.

The results indicate that the climate impact of using rPET versus virgin PET is relatively modest when considering the entire product lifecycle. Therefore, the conclusions are not highly sensitive to changes in the average market sports t-shirt composition.

Nevertheless, it's essential to note that the estimated potential climate impact reductions associated with the Ecolabel requirements on rPET content are directly tied to the assumptions about rPET content in the average market t-shirt. Any percentage change in the rPET content of the average market t-shirt will lower the CO_2-eq emissions of it and thereby lower the reduction potential of the Ecolabelled sports t-shirt



1) Textilie Exchange (2022) - Preferred Fiber & Materials Market Report

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4. Life Cycle Inventory, LCI

Data sources

Data used in the assessment is based on ecoinvent v. 3.9.1 and literature

Process data

The process data for the calculations of greenhouse gas emissions are based on a combination of processes from the LCA-database ecoinvent, together with literature regarding LCA's on relevant materials. Processes on the production of virgin polyester fabric has been constructed from ecoinvent processes, as well with the recycled PET material. The processes to produce the elastane textile has been found in literature.

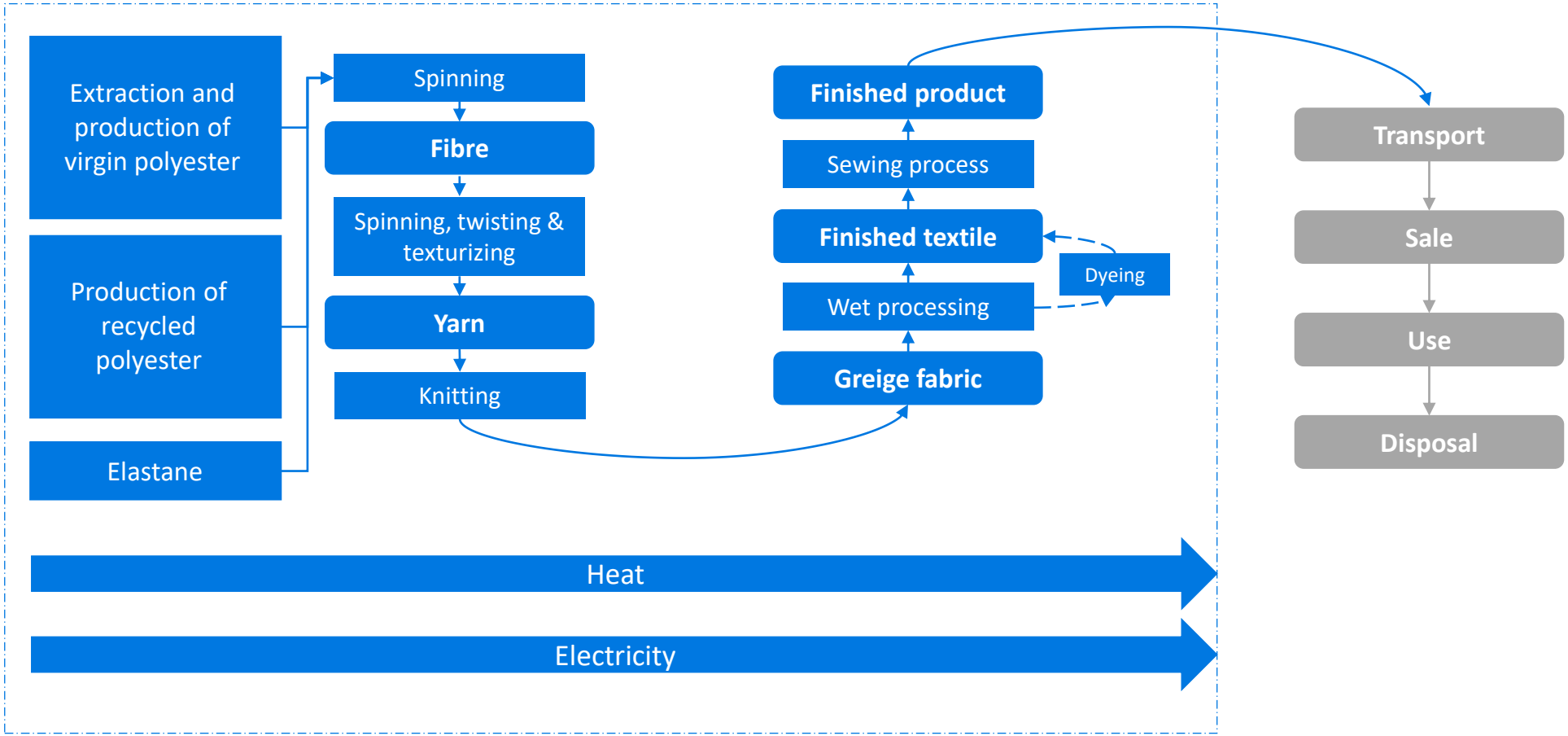
Detailed descriptions of the processes can be found in appendix.

Sources

The production process steps, and the estimated material waste is based on the following sources:

- Maeen Md. Khairul Akter, Upama Nasrin Haq, Md. Mazedul Islam, Mohammad Abbas Uddin, *Textile-apparel manufacturing and material waste management in the circular economy: A conceptual model to achieve sustainable development goal (SDG) 12 for Bangladesh*, Cleaner Environmental Systems, Volume 4, 2022.
- Prabod Munasinghe, Angela Druckman, D.G.K. Dissanayake, *A systematic review of the life cycle inventory of clothing,* Journal of Cleaner Production, Volume 320, 2021.
- Prakash Khude, *A Review on Energy Management in Textile Industry,* 2017
- Sandra Roos, Gustav Sandin, Bahareh Zamani and Greg Peters, *Environmental assessment of Swedish fashion consumption. Five garments – sustainable futures,* 2015.

System boundaries



Not in the diagram:
Waste of material - occurs in multiple steps of the production chain, and this is also accounted for.

The route of the textile

Raw material and Fibre production

The raw material extraction and fibre production is located globally, focusing on the countries such as Bangladesh and India

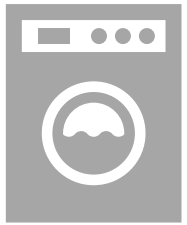
Textile production and stitching

The textile production is assumed to take place in countries with energy mixes similar to China, Bangladesh and Turkey. When the sports t-shirt is getting stitched a 16% waste is assumed[1].

Transport

An average transport is assumed with 95% container ship and 5% truck. Based on the distance of the three biggest export countries of clothes for the Nordic countries (China, Bangladesh and Turkey).

Use



It is assumed that the sports t-shirt is washed a total of 44 times, following the specification of 45 uses defined in the PEFCR[2] for apparel and footwear.

End-of-life

The end-of-life scenario assumed for the sports t-shirt is waste incineration with energy recovery in Europe [1].

Included processes

Only included in sensitivity analysis

1: Roos et al (2015), Environmental assessment of Swedish fashion consumption. Five Garments – sustainable futures. Approved by Mistra Future Fashion.
2: Quantis (2022), Draft product environmental footprint category rules (PEFCR), Apparel and footwear.

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5. Life Cycle Impact Assessment, LCIA

Life Cycle Impact Assessment method: IPCC 2021 GWP 100a

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What is life cycle impact assessment, LCIA?

The impact assessment in a LCA is where the possible environmental impacts are calculated and assessed. This is done by translating the physical flows from the life cycle inventory into environmental impacts in the chosen impact categories.

There is a range of different life cycle impact assessment methods to choose from. The most used ones are built into LCA software and included in the ecoinvent database extracts.

Bearing in mind the purpose of this study, which is to assess the potential reduction of GHG emissions associated with choosing an ecolabelled sports t-shirt compared to a non-ecolabelled alternative, the impact assessment method IPCC 2021 GWP 100a was chosen.

LCIA method IPCC 2021 GWP 100a

The chosen impact assessment method in this study is IPCC 2021 GWP 100a[1], which focuses on climate change as the only impact category. The assessment method translates various greenhouse gas emissions into possible climate change impacts measured in the common unit "kg CO_2-equivalents" (kg CO_2-eq) on a time horizon of 100 years.

Greenhouse gasses have varying life spans in the atmosphere. As an example, CO_2 resides in the atmosphere for much longer than CH_4 (methane) before moving on in the cycle between earth, water, plants and air[2]. The global warming potential (GWP) of a greenhouse gas thus depends on the chosen time frame. The most often used time frame is 100 years, which is also chosen here. This is referred to as GWP 100a (Global Warming Potential for 100 years).

In a conventional LCA, up to 15-20 impact categories would be considered, with climate change being just one of them[3]. In other words, a complete LCA would give a more holistic picture of environmental sustainability than IPCC 2013 GWP 100a. However, only showing results for climate change could be easier to understand and communicate. An LCA which solely focuses on climate change can also be called a Carbon Footprint.

1: Developed by IPCC (Intergovernmental Panel on Climate Change) https://www.ipcc.ch/.
2: https://www.ipcc.ch/report/ar5/wg1/.
3: Hauschild et al. 2018: https://orbit.dtu.dk/en/publications/life-cycle-assessment-theory-and-practice

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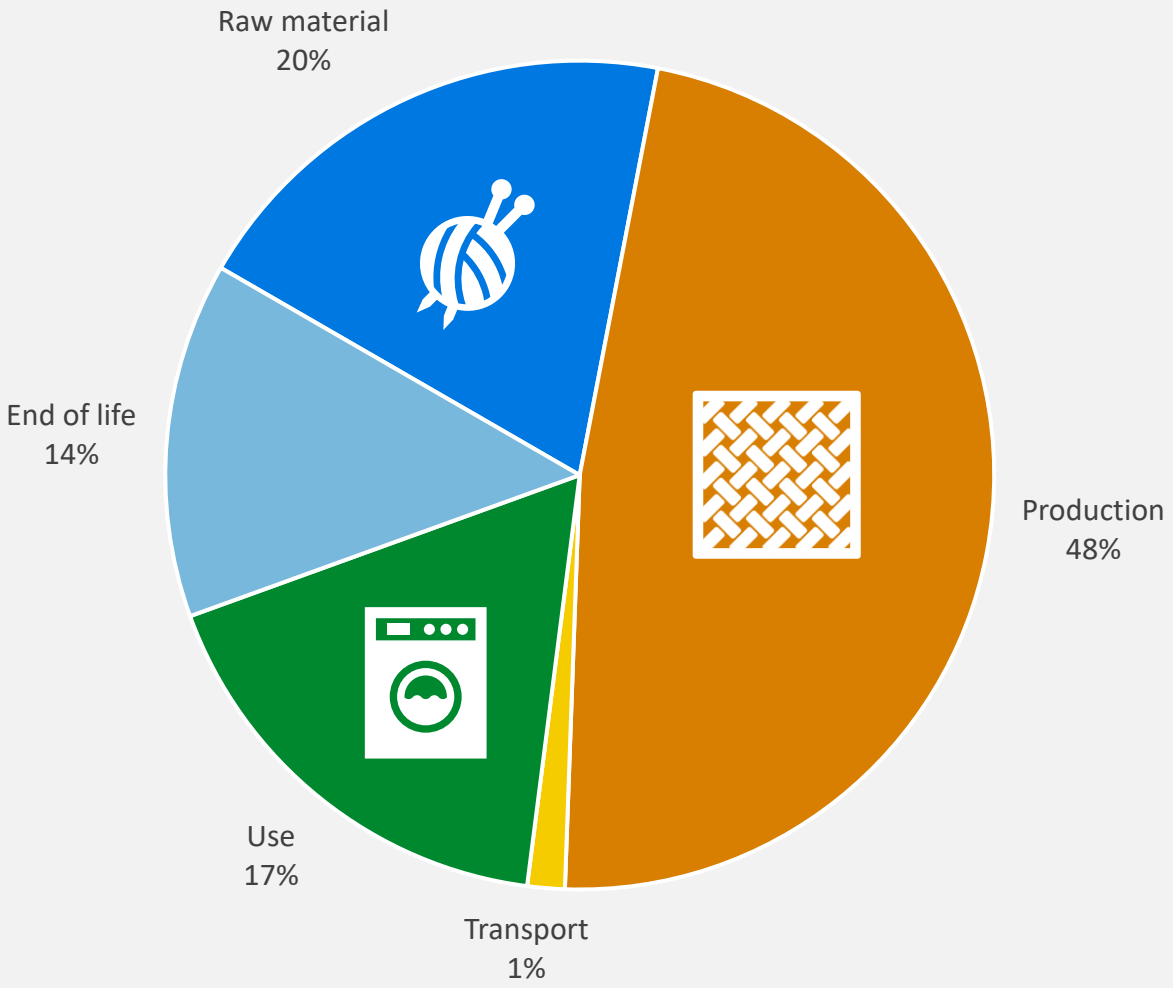
6. Interpretation

The production phase is contributing the most to the CO_2-eq emissions from the Ecolabel sports t-shirt



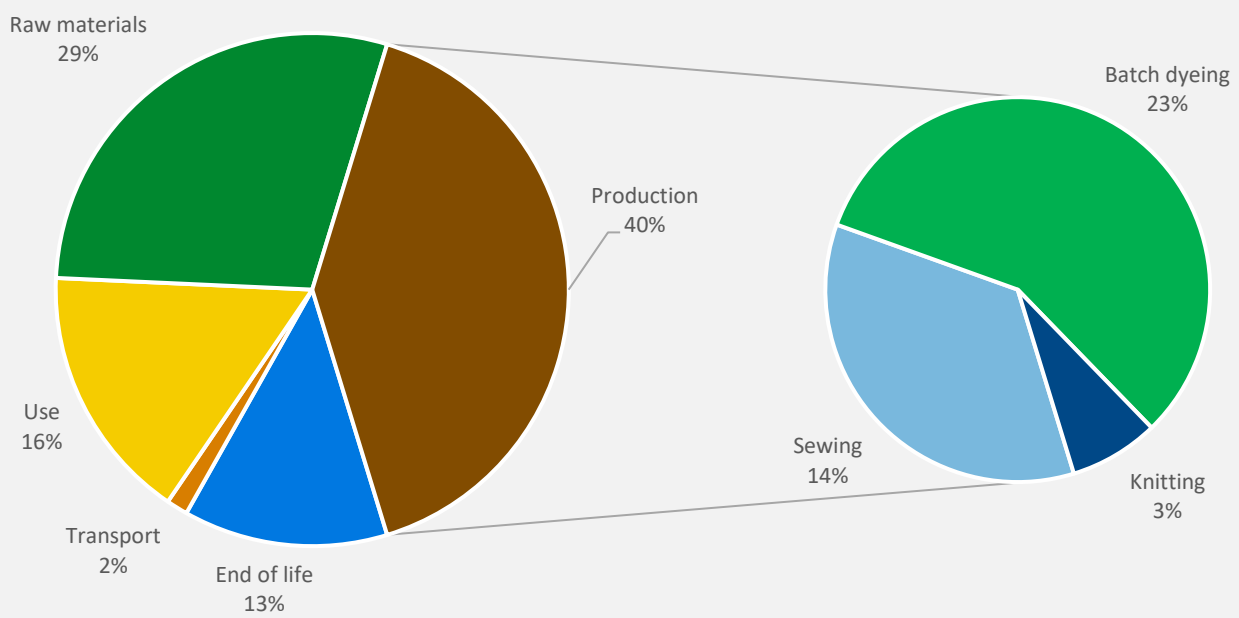
Description
The cradle-to-gate processes (raw material and production) accounts for ~68% of the cradle-to-grave emissions of greenhouse gasses (GHGs) for a sports t-shirt. The production phase is the most significant contributor to the GHG-emissions associated with the sports t-shirt.

The exclusion of the use-phase and end of life-phase
The use-phase and end of life-phase has been calculated in this study but is not part of the focus or main results. This is caused by the fact that the Nordic Swan Ecolabel cannot pose criteria on that part of the life cycle as it is dependent on the consumer. However, to show the potential of the Nordic Swan Ecolabel on the full life cycle of the sport t-shirt is necessary for providing the entire picture and CO_2-eq reduction potential.

The sports t-shirt in this sensitivity analysis is an Ecolabel sports t-shirt consisting of the following materials

There is ~3% percentage points in difference in how much the raw material acquisition and production contribute to the CO_2-eq emissions between an ecolabelled and a market average non-ecolabelled sport t-shirts.

Almost 60% of the impacts in the production-phase are related to the dyeing of textile

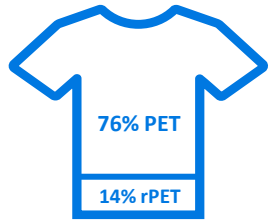


Description

To the left is a graph showing the contribution of the different processes in relation to the overall CO_2-eq emissions stemming from the life cycle of the sports t-shirt.

A hotspot analysis shows that the largest contribution to greenhouse gas emissions in the production comes from dying the fabric. There are no differences in how much each life cycle phase contributes to the CO2-eq emissions between the ecolabelled and the non-ecolabelled sports t-shirt.

The sports t-shirt in this sensitivity analysis consist of the following materials



However, there are only small differences in the contribution of the processes to the CO2-eq emission when looking at the Ecolabelled sports t-shirt and the sports t-shirt of 100% newly produced PET. Thereby, the hotspots in the production process are the same in all scenarios.

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7. Appendix

Mix of electricity and heat for the Nordic countries

Appendix

The used electricity mix and heat mix are based on a weighted average of the total energy consumption in each of the Nordic countries (Denmark, Sweden, Norway, Finland and Iceland). National grid mixes are taken from ecoinvent 3.9.1.

Country	Total electricity use [ktoe]	Share of total Nordic electricity use (%)
Denmark	17.024	13%
Sweden	49.766	37%
Norway	28.326	21%
Finland	33.985	25%
Iceland	6.142	5%

Country	Total natural gas use [ktoe]	Share of total Nordic heat mix (%)
Denmark	2.821.668	26%
Sweden	851.091	8%
Norway	4.617.436	43%
Finland	2.406.717	23%
Iceland	0	0%

Source: http://www.fao.org/aquastat/statistics/query/results.html

Adaptions to the ecoinvent process

Edited processes from ecoinvent

Raw materials, rPET	Changes	Comment
Market for polyethylene terephthalate, granulate, amorphous, recycled {Europe without Switzerland}	Edited, Added	To get 50% EU and 50% RoW
Market for polyethylene terephthalate, granulate, amorphous {GLO}	Subtracted	Taking out the polyethylene included in the fibre, polyester process
Market for fibre, polyester {GLO}	Edited	16% added for waste textile in the production
Market for polyethylene terephthalate, granulate, amorphous, recycled {RoW}	Edited, Added	To get 50% EU and 50% RoW
Treatment of waste polyethylene terephthalate, sanitary landfill {RoW}	-	65% assumed going to sanitary
Treatment of waste polyethylene terephthalate, open dump, moist infiltration class (300mm) {GLO}	-	45% assumed going to open dump

Raw materials, new polyester fibre	Changes	Comment
Market for fibre, polyester {GLO}	-	16% added for waste textile in the production, source: ecoinvent
Treatment of waste polyethylene terephthalate, sanitary landfill {RoW}	-	see comment on Raw material, rPET
Treatment of waste polyethylene terephthalate, open dump, moist infiltration class (300mm) {GLO}	-	see comment on Raw material, rPET

Raw materials, new elastane	Changes	Comment
Market for polyurethane, flexible foam, flame retardant{GLO}	-	
Market for lubricating oil	-	50% EU and 50% RoW
Dimethylacetamide production	-	
Market for electricity, medium voltage	Edited	El mix - modelled after Roos et al (2015)
Market for electricity, medium voltage	Edited	El mix - modelled after Roos et al (2015)
Market for electricity, medium voltage	Edited	El mix - modelled after Roos et al (2015)
Market for lubricating oil	-	50% EU and 50% RoW
Treatment of waste polyethylene terephthalate, sanitary landfill	-	see comment on Raw material, rPET, NB: taken treatment of PET
Treatment of waste polyethylene terephthalate, open dump, moist infiltration class (300mm)	-	see comment on Raw material, rPET, NB: taken treatment of PET

Adaptions to the ecoinvent process

Edited processes from ecoinvent

Polyester, knitted, coloured	Changes	Comment
Building construction, hall, steel construction	-	50% EU
Building construction, hall, steel construction	-	50% RoW
Market for lubricating oil	-	50% EU
Market for lubricating oil	-	50% RoW
Market for electricity, medium voltage {BD}	-	
Market for acetic acid, without water, in 98% solution state {GLO}	-	
Market for building, hall {GLO}	-	
Market for chemical, organic	-	
Market for hydrogen peroxide, without water, in 50% solution state	-	
Market for soap	-	
Market for sodium chloride, powder {GLO}	-	
Market for sodium hydroxide, without water, in 50% solution state	-	
Market group for tap water	-	
Market for diesel, burned in diesel-electric generating set, 18.5kW	-	
Market group for electricity, low voltage	-	
Output:		
Waste mineral oil	-	
Waste yarn and waste textile	-	
Wastewater from textile production {GLO}| market for wastewater from textile production | Conseq, U	-	

Adaptions to the ecoinvent process

Edited processes from ecoinvent

Stitching of shirt	Changes	Comment
Market for electricity, medium voltage {CN- ECGC}	-	sewing + ironing - own electricity shares
Market for electricity, medium voltage {BD}	-	sewing - own electricity shares
Market for electricity, medium voltage {TR}	-	sewing - own electricity shares
Heat production, natural gas, at boiler condensing modulating >100kW {RoW}	-	
Market group for tap water {GLO}	-	

Transport to Nordic Countries	Changes	Comment
Transport, freight, sea, container ship {GLO}	95% of the total distance	The distance is based on average distance of the 3 biggests countries that export textile to the Nordic countries.
Transport, freight, lorry 3.5-7.5 metric ton, EURO6	5% of the total distance	The distance is based on average distance inside the Nordic countries

Use phase*	Changes	Comment
Market for washing machine {GLO}	-	
Market group for electricity, low voltage	Edited	The market for electricity is based on the mix eletricity for the Nordic Countries
Tap water production, conventional treatment {Europe without Switzerland}	-	
Non-ionic surfactant {GLO}	-	
Heat and power co-generation, natural gas, conventional, Nordic countries	Edited	The heating amount is based on the mix heating for the Nordic Countries
Output:		
Market for wastewater, average {Europe without Switzerland}	-	

End-of-life	Changes	Comment
Treatment of waste polyethylene terephthalate, municipal incineration {CH}	-	

* The use phase assumes that the T-shirt is washed 44 times as defined by the PEFCR for Apparel and Footwear

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